

CLAIMS

What is claimed is:

1. A method for forming an investment casting mold comprising:

forming a shell over a pattern comprising a hydrocarbon-based body with a refractory metal-based core at least partially embedded in the body;

substantially removing the body from the shell;

strengthening the shell by heating in a first atmosphere of a first composition; and

further strengthening the shell by heating in a vacuum or second atmosphere of a second composition, different than the first composition.

2. The method of claim 1 wherein:

the heating of the strengthening is substantially at 800-1100F; and

the heating of the further strengthening is substantially at 1400-1600F.

3. The method of claim 1 wherein:

the heating of the further strengthening is a preheating prior to an introduction of molten metal to the mold.

4. The method of claim 1 wherein:

said first composition is more oxidative than said second composition.

5. The method of claim 1 used to fabricate a gas turbine engine turbine airfoil element.

6. The method of claim 1 wherein:

the first composition consists in major part of air.

7. The method of claim 6 wherein:  
the second composition consists in major part of one or more inert gasses.
8. The method of claim 1 wherein:  
the first composition has an oxygen partial pressure of at least fifteen kPa.
9. The method of claim 8 wherein:  
the second composition has an oxygen partial pressure of no more than ten kPa.
10. The method of claim 1 further comprising:  
fully embedding the refractory metal-based core in the hydrocarbon-based body.
11. The method of claim 1 wherein:  
the strengthening is effective to provide the shell with a first modulus of rupture (MOR) strength of 65-80% of a maximum MOR strength; and  
the further strengthening is effective to provide the shell with a second MOR strength of at least 85% of said maximum MOR strength.
12. The method of claim 11 wherein:  
after said substantially removing, the shell has a preliminary MOR strength of no more than 50% of said maximum MOR strength.
13. A method for investment casting comprising:  
forming an investment casting mold as in claim 1;  
introducing molten metal to the mold;  
permitting the molten metal to solidify; and

destructively removing the mold.

14. The method of claim 13 wherein:

a temperature of the shell does not fall below 1200F between the further strengthening and the introducing.

15. A method for forming an investment casting mold comprising:

applying one or more coating layers to a sacrificial pattern having a wax first portion and a second portion comprising a refractory metal core;

steam dewaxing of the coated pattern so as to remove a major portion of the pattern first portion and leaving the second portion within a shell formed by the coating layers;

first heating the shell to harden the shell and remove residues or byproducts of the wax, the first heating being effective to provide the shell with a first modulus of rupture (MOR) strength no more than 85% of a maximum MOR strength; and

second heating of the shell to strengthen the shell to a second MOR strength.

16. The method of claim 15 wherein:

the first heating is in an oxidizing atmosphere; and  
the second heating is in vacuum or an inert atmosphere.

17. The method of claim 15 wherein:

the second heating is a preheating prior to molten metal introduction.

18. The method of claim 15 wherein:

the first MOR strength is 65-80% of said maximum MOR strength; and

the second heating is effective so that the second MOR strength is at least 85% of said maximum MOR strength.

19. The method of claim 15 wherein:

the first heating has a peak temperature between 800F and 1100F; and

the second heating has a peak temperature in excess of 1500F.

20. The method of claim 15 wherein:

the first heating has a temperature between 800F and 1100F for at least 2.0 hours; and

the second heating has a temperature in excess of 1500F for at least 1.0 hour.

21. The method of claim 15 wherein the second portion comprises:

said refractory metal core;

a coating on said refractory metal core; and

a ceramic core secured to said refractory metal core prior to the applying.

22. A method for forming an investment casting mold comprising:

applying one or more coating layers to a sacrificial pattern having a first portion for forming a mold void and a second portion for forming a portion of the mold;

a first step for removing a major portion of the pattern first portion and leaving the second portion within a shell formed by the coating layers;

a second step for initial hardening of the shell effective to provide the shell with a first modulus of rupture (MOR) strength no more than 85% of a maximum MOR strength; and

a third step for further hardening of the shell without substantial degradation of the pattern second portion.

23. The method of claim 22 used to fabricate a gas turbine engine component.

24. The method of claim 22 wherein:

the second step is essentially performed under an oxygen partial pressure of at least twenty kPa.

the third step is essentially performed under an oxygen partial pressure of no more than five kPa.

25. A method for investment casting comprising:

forming an investment casting mold as in claim 22;

introducing molten metal to the mold;

permitting the molten metal to solidify; and

destructively removing the investment casting mold.

26. A system for forming an investment casting mold comprising:

means for forming a shell over a pattern, the pattern comprising a hydrocarbon-based body with a refractory metal-based core at least partially embedded in the body;

means for substantially removing the body from the shell;

means for strengthening the shell by heating in a first atmosphere of a first composition; and

means for further strengthening the shell by heating in a vacuum or second atmosphere of a second composition, different than the first composition.